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Article

Analysis of Factors Influencing Students' Access to Mathematics Education in the Form of MOOC

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Abstract: Restricting the movement of students because of COVID-19 requires expanding the offer of online education. Online education should reflect the principles of pedagogical constructivism to ensure the development of students' cognitive and social competencies. The paper describes the preparatory course of mathematics, realized in the form of MOOC. This course was created and implemented based on the principles of pedagogical constructivism. The analysis of the respondents' approach to MOOC revealed a difference between bachelor and master students in the use of MOOC. Bachelors found a strong correlation between their approach to MOOCs and the way they are educated in secondary schools. The results of the research point to the need of more emphasis should be placed on advancing the learner's skills in navigating and analysing information. The questionnaire filled in by the participants also monitored the students' access to learning. The results of the experiment confirmed the connection between the preferred approach to learning and students' activities within the MOOC.

Keywords: constructivism; mathematics learning; MOOC; new teaching techniques; students' access to MOOC

1. Introduction

Recently, many pedagogical experts have questioned traditional teaching methods such as lectures and testing [1] (pp. 167–202), [2] (pp. 3–17). According to Mascolo [2], the basis of pupil-centred education is constructivism. Constructivism is based on the European genetic epistemology of Jean Piaget and American cognitive psychology. Constructivist epistemology includes cognitive constructivism and social constructivism [3] (pp. 241–250). Cognitive constructivism pursues the individual development of knowledge through interaction with the environment, and social constructivism refers to the dialogue of students with each other and the teacher and to the social context in which learning takes place [4] (pp. 61–86). According to Lave and Wenger, an important part of constructivism is social constructivism, which focuses on cultural and social learning conditions, on social interaction in learning [3,5] (pp. 241–250). Pedagogical constructivism is a combination of cognitive and social constructivism and demands that teaching should use authentic problem solving, creative thinking and group work [5]. Medová and Bakusová [6] (pp. 142–150) stressed the role of real-life problems in constructivist mathematics education. Astin [7] also focused on group work in his research.

Recently, we have seen a massive increase in the offer of various online courses, even for university students. There are countries where online courses have become an integral part of teaching, especially at universities. In the USA, for example, more than 30% of university students attend at least one online course [8]. Using state-of-the-art computer technologies, online courses offer students a wide range of engaging and interactive learning environments that have demonstrated support for satisfaction, motivation and persistence among participants [9] (pp. 435–447), [10] (pp. 24–32), [11] (pp. 221–231), [12] (pp. 306–331).

Online courses encourage students to be independent, to develop the skills of personal reflection and abstract conceptualization [13] (pp. 227–243), [14] (pp. 309–328). For more success in using online courses [15] (pp. 1–28) suggests more emphasis should be placed on advancing the learner's skills in navigating and analysing information.

Another, relatively new, but especially effective element in online learning are the so-called massive open online courses or MOOC. The term "massive open online course," or MOOC, was first used to describe a course on learning theory taught by George Siemens and Stephen Downes at the University of Manitoba in 2008. According to Downes, the idea was to "invite the rest of the world to join the 25 students who were taking the course for credit" [16].

MOOC is based on the principle of sharing and freedom. According to Jeffrey [17], this is "self-service learning and crowdsourced teaching".

MOOC courses meet with several positive responses in the professional community. For example, Friedman [18] (pp. 175–186) considers the MOOC a breakthrough in higher education, and Mozoué [19] sees them as an alternative to full-time education and making education accessible to a wider range of society. There are also doubts about their contribution to higher education. Several higher education analysts are sceptical and express their doubts as to whether the MOOC is an adequate alternative to classical higher education or online education, especially in terms of teaching and access to students [8,20] (pp. 7–26), [21] (pp. 87–110). They also point out that the use of MOOC requires participants to be able to work independently and thus have the necessary level of critical literacy and the ability to navigate the course. Therefore, according to Kop, Fournier, & Mak [22] (pp. 74–93), more experienced and independent students are more successful in this environment. It also happens that many participants are struggling with a lack of instructional support at the MOOC and do not complete their courses.

There are currently several empirical studies that evaluate not only the MOOC teaching strategy but also the results of MOOC-related learning. According to Toven-Lindsey [23] (pp. 1–12) and Rhoads and Lozano [21] (pp. 87–110), there are considerable differences in pedagogical approaches, most courses still use elements that are common in traditional classes, including lectures, multi-choice assessments, and discussions about current groups.

Currently, there is already an offer of mass open online courses (MOOC) in Slovakia, but such offer is limited—only in some universities are MOOC offered for selected courses, as a means of supporting the quality of education. This is even though external students make up approximately one quarter of university students. According to [24] (pp. 451–460), due to many online learning opportunities, including MOOC courses, it is necessary to analyse their quality and to improve the effectiveness of education using analytical methods. One of the first Slovak universities involved in the MOOC project since 2013 is the Slovak University of Technology. Slovakia was also involved in the project BizMOOC—Knowledge Alliance to enable a European-wide exploitation of the potential of MOOCs for the world of business Programme: Erasmus+. It was found in the project that one of the major obstacles to using MOOC is the language barrier (see www.bizmooc.eu). The above findings showed the need to create MOOC in the national language in Slovakia. The aim of our research was to create a preparatory MOOC of mathematics that would consider the principles of pedagogical constructivism and to conduct research on the behaviour of students in using this course. In this way, we wanted to find out whether not only the cognitive but also the social component of the student's personality in relation to his/her approach to learning develops within the MOOC. This would determine whether MOOC can be a suitable alternative to full-time education.

2. Materials and Methods

2.1. Objective

For several years, many Slovak universities have introduced the so-called "tutoring mathematics" in the form of various mathematics courses. These courses are intended primarily for students admitted to the 1st year of higher education and are usually organized in full-time form lasting from 3 to 5 days. It was this situation that motivated us to create a pilot preparatory e-learning course in mathematics. In our case, we chose a relatively under-used MOOC model in Slovakia, where students can not only educate themselves but also discuss and present their problem-solving procedures. In addition to the above, we were motivated by idea of Giroux [25], according to which students should not only be educated, but also be active participants in the learning process. Our research team has set a goal to develop a pilot mathematics preparatory course in the form of MOOC and examine its use by students. At the same time, we investigated whether, in addition to the development of cognitive competencies, participants in the course also develop social competencies. In the case of the development of both competencies, the MOOC in the proposed form could be a suitable alternative to the full-time form of education.

As courses of a similar type were not available in Slovakia so far, we developed the course ourselves and offered it to the students and we not only observed the extent to which the students used the course, but we also considered it necessary to find out the students' reactions to the product. We were therefore interested in the extent to which students will use the different parts of the MOOC and what attitude they will take to it.

The MOOC course lasted one month and was made available to students admitted to the first year of undergraduate and graduate study at the technical faculty of a selected university in Slovakia. There were separate MOOC modules for each stage of the study with respect to the achieved education.

During enrolment in the first year (both undergraduate and graduate), students were acquainted with a preparatory course in mathematics in the form of the MOOC containing the "mathematical minimum" needed to master mathematics in the given field of study for which they were admitted. Created MOOC and possibilities of its use were introduced to students by MOOC authors themselves. At the same time, each student received access data to the portal. The access data were anonymous for the research team, only used to monitor the activities of individual students within the MOOC. These data were also used in the final questionnaire. Student activity data served as data for statistical evaluation of MOOC rate and usage. Our MOOC consisted of the following modules: Module 1—algebraic equations and inequalities, Module 2—non-algebraic equations and inequalities, Module 3—functions, Module 4—elemental geometry. Each module was given a week within the MOOC. MOOC was created and launched on the website: https://www.mooc.km.fpv.ukf.sk/, which we were developing for a long time. This training system works both in Slovak and English and the course materials for individual modules were gradually made available. The study materials were divided into two parts. The first part consisted of theoretical bases of the studied problems such as definitions of basic terms (8 pdf files) and assignments of tasks in text form (8 pdf files) and the second part consisted of sample examples in audio-visual form. The video sequences included instructions for solving basic sample examples for individual modules (32 video sequences). Solutions of various problem tasks supporting the construction of new computational strategies for students were the subject of webinars. Every Friday, the webinar was held twice (at 10:00 and 17:00), which was focused on problematic issues related to topics provided to MOOC participants in each week. The webinar was always led by a member of the author team. The aim of the webinar was to support the ability of students to create their own solutions of given tasks with creative use of already acquired theoretical knowledge and skills with solving standard tasks. The principles of pedagogical constructivism were consistently applied to webinars. The heuristic general didactic method was used, in which the teacher acted as a moderator of the participants' discussions. Each registered participant automatically became a member of the MOOC discussion forum without teacher participation. At the same time participants could create different discussion subgroups—these subgroups could be created by the participants. Another possibility through MOOC that we created was the possibility to address the teacher in the form of a question or by requesting to check the correctness of the task. From the questions asked to the teacher, we gradually created the content in the "Frequently Asked Questions" menu. For each of the topics covered, exercises were also available for download with the option to send suggested solutions to the teacher for review.

2.2. Sample

We were interested in the extent to which students will use the individual parts of our MOOC course and what attitude they will take towards it. The research took place in September before the beginning of the winter term of the academic year 2018/2019 at a selected university of the Slovak Republic. Respondents of the research were engineering fields of study students, namely 48 undergraduate students and 35 graduate students. The respondents were between 19 and 26 years of age. Participation in MOOC was voluntary, which was also reflected in students' lower interest from compared commonly used full-time form.

2.3. Information Collection Tools

The data necessary for the evaluation of the research were obtained by monitoring the activity of students involved in the MOOC preparatory course of Mathematics. We monitored the number of views of each video sequence and the number of downloads of study materials. An important source of data was the content and form of discussions among students within the discussion group. The administrator was able to track the overall activity of each MOOC member, so it was possible to determine the priorities of each MOOC member when choosing the options offered within the course. After completing the MOOC course, respondents completed a questionnaire. All students who participated in the MOOC were able to complete the questionnaire, regardless of whether they completed the course or not.

3. Results and Discussion

The basis for evaluating the suitability and usability of MOOC as a preparatory course in mathematics was a questionnaire developed and used by Aharony and Bar-Ilan [26] (pp. 146–152). Just like the authors of the questionnaire, in our case we also observed 5 areas in the questionnaire:

1. Personal data
2. Perception of usefulness questionnaire (PU) (3 questions)
3. Ease of Use Perception Questionnaire (PEOU) (3 questions)
4. Learning Strategies (LS) (14 questions)
5. Cognitive Assessment Questionnaire (CAQ) (9 questions)

The 4th part of the questionnaire—Learning Strategies (LS), which reflects the student's approach to learning and education, was very important for us. According to [26] there is the deep learning versus the surface learning approach; terms that are based on the early work of Marton and Säljö [27]. Deep learners tend to seek for their 'inner self' through the learning process [28,29].

Contrarily, surface learners learn only important and essential facts, applying minimum study efforts [28]. A surface learning approach is associated with students who study only superficial details [30]. They are concerned with the time needed to accomplish the learning task; therefore, they try to choose the quickest way to accomplish their learning assignment, without asking further questions and without fully understanding the text meanings. Surface learners usually memorize facts; thus, meta-cognitive skills are mostly not involved in their learning process [28].

Cognitive appraisals of threat and challenge refer to "dispositions to appraise ongoing relation-ships with the environment consistently in one way or another" [31] (p. 138). Cognitive appraisal addresses the person's evaluation of events for his or her well-being [32].

For the reasons stated above and also in accordance with [26], we divided the fourth area of the questionnaire into two parts (areas), namely: learning strategies: deep learning (LS-D), consisting of questions 1, 3, 6, 8, 12, 13 and surface learning (LS-S), which consisted of questions 2, 4, 5, 7, 10, 11, 14. For the same reasons, we divided the fifth questionnaire into two parts: threat perception (CAQ-T), consisting of questions 1, 2, 3, 4, 6, 7, and challenge perception (CAQ-CH), which consisted of questions 5, 8, 9.

Part of our research was also tracking the activities of students who attended the MOOC course. We divided the activities into two areas: cognitive constructivism (MOOC-CC) and social constructivism (MOOC-SC).

Subsequently, we identified research questions:

Q1: Are there significant differences in student responses in each area of the questionnaire relative to their degree (bachelor or master)?

Q2: Is there a relationship between student responses in each questionnaire area?

Q3: Is there a relationship between students' access to education and their attitudes to using MOOC?

Q4: Is there a relationship between students' access to education and the use of individual areas of activity in our MOOC course?

Q5: Is there a relationship between the perception of new situations in MOOC among students and the use of individual areas of activity in our MOOC course?

To find answers to individual research questions (Q1–Q5) we analysed the results obtained by the questionnaire method as well as by monitoring the respondents' activities. There was an answer to each question on the 5-point Likert scale, where 1 means "absolutely disagree" and 5 means "totally agree". The results obtained in our research by the questionnaire method in both groups of students are illustrated in the following figures (Figures 1–6).

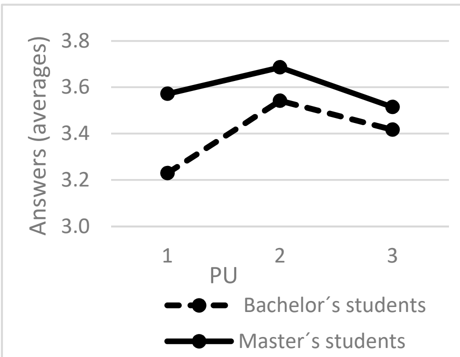

Figure 1. Answers of undergraduate and graduate students in PU (average values).

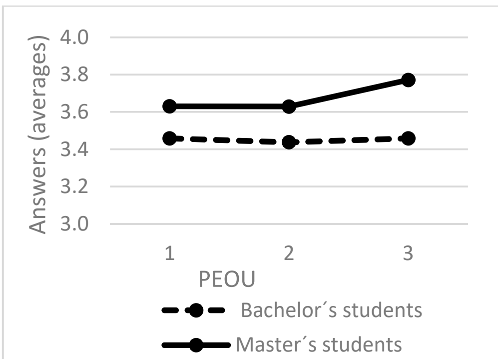

Figure 2. Answers of undergraduate and graduate students in PEOU (average values).

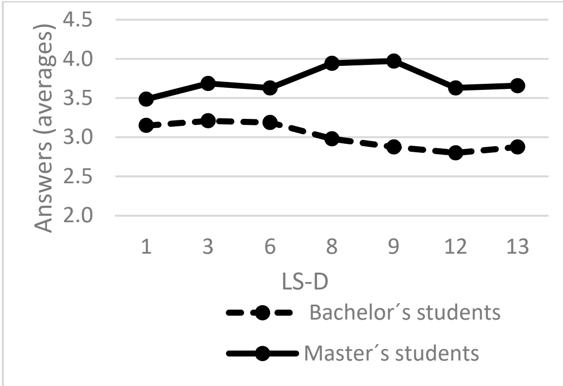

Figure 3. Answers of undergraduate and graduate students in LS-D.

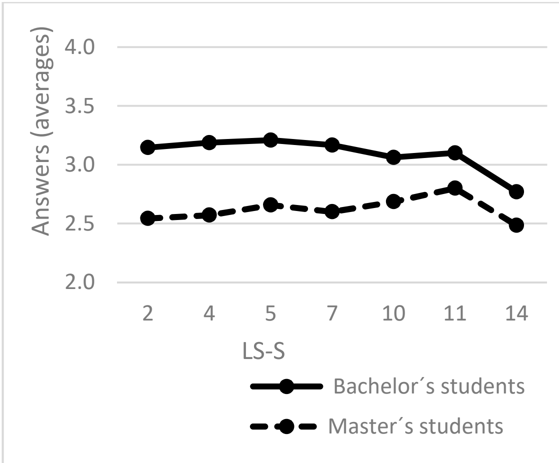

Figure 4. Answers of undergraduate and graduate students in LS-S.

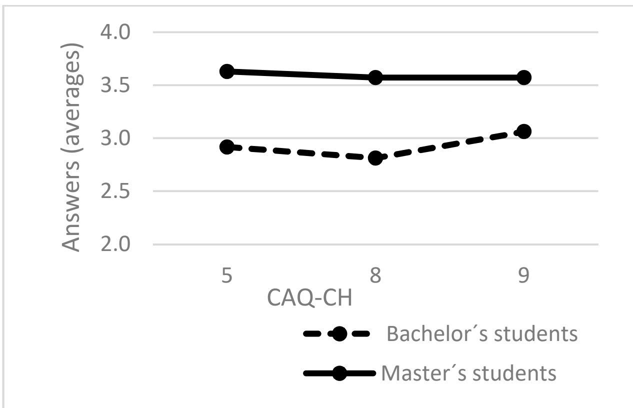

Figure 5. Answers of undergraduate and graduate students in CAQ-CH.

In Figures 1–6 we can see that there are differences between the answers of students of undergraduate and graduate study to questions in individual areas of the questionnaire. We wondered if the differences are statistically significant.

The statistical significance of the differences between the two groups of students in the answers to the questions was verified in each area of the questionnaire (PU, PEOU, LS-D, LS-S, CAQ-CH and CAQ-T) based on calculated values, called total score. As the assumption of a normal distribution of observed traits was not met, we used the non-parametric Wilcoxon two-sample test to verify the Q1 research hypothesis [32].

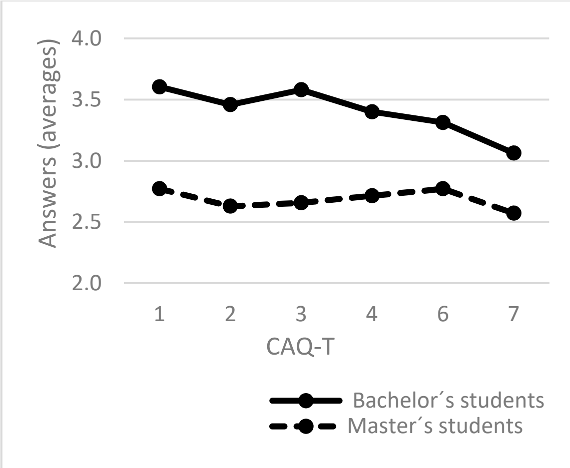

Figure 6. Answers of undergraduate and graduate students in CAQ-T.

In our case, the first selective file consists of undergraduate students and second file consists of graduate students. The results of the selected area of the questionnaire (total score) of both groups of students represent the realization of two mutually independent random samples from continuous distributions. We conducted Wilcoxon's two-sample test in STATISTICA.

The results obtained using Wilcoxon's two-sample test were summarized in the following Table 1.

Table 1. The results of Wilcoxon's two-sample test.

Questionnaire Area	*Z*	*p*
PU	−0.810	0.418
PEOU	−1.600	0.109
LS-D	−3.489	0.000 *
LS-S	1.393	0.164
CAQ-CH	−3.531	0.000 *
CAQ-T	5.368	0.000 *

Note: Values exceeding the critical value are indicated * in the table.

Since the calculated probability value $p < 0.05$, in three cases—in the LS-D, CAQ-CH and CAQ-T areas, the hypothesis H_0 is rejected in all three cases at the significance level $p = 0.01$ and we can say that among the undergraduate and graduate groups is a significant difference in the answers to the questionnaires in the LS-D, CAQ-CH and CAQ-T.

Based on the results obtained in the statistical analysis of PU, PEOU and LS-S questionnaire, the hypothesis H_0 cannot be rejected, i.e., the observed differences are not statistically significant.

Analysis of Student Activity within MOOC

Figures 7 and 8 show the average MOOC visit values for each activity. The activities of undergraduate and graduate students were evaluated separately. This division was based on the results of the questionnaire in the field of LS, where it turned out that undergraduate and graduate students have different approaches to education. While graduate students prefer deep learning, undergraduate students prefer surface learning. Therefore, when answering other research questions, we evaluated the individual parts for undergraduate and graduate students separately.

We divided the activities in the created MOOC course into two parts. The first part was called "Cognitive Constructivism", which included those activities where there was no cooperation with other course participants or with the teacher. They were theory, video, and exercises to practice. The average utilization of the individual activities is shown in Figure 7.

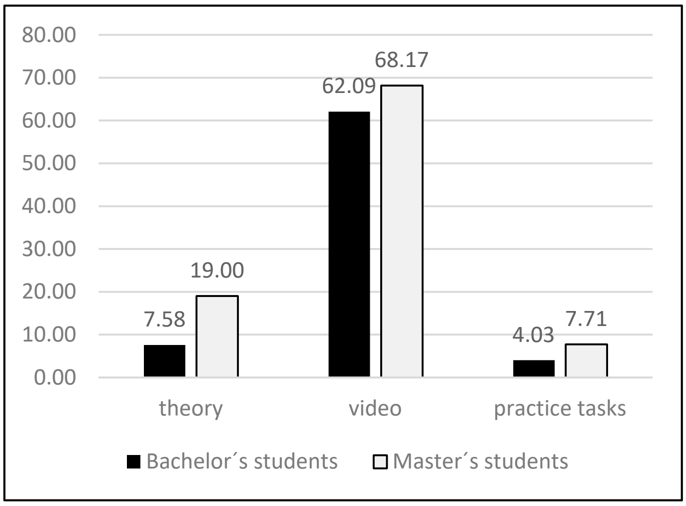

Figure 7. Average visit in options under 'Cognitive constructivism'.

In both groups of students, the most attention was paid to video sequences. In all activities graduate students were more active in all activities. The biggest difference was in the use of the offer of the necessary theoretical knowledge on the individual topics covered within our MOOC.

The second part consisted of activities in which the participants cooperated with each other and possibly with the teacher. We called this part "Social Constructivism" and it included activities: a webinar, a question to the teacher, a discussion forum, frequently asked questions.

Based on the results shown in Figure 8, graduate students were more active in the second part activities, and even more than in the first part. Only in the activity "Question to the teacher" were undergraduate students more active. We interpret this because of the fact that undergraduate students come from a high school (secondary school) environment where the teacher has a dominant position in pupils learning [33].

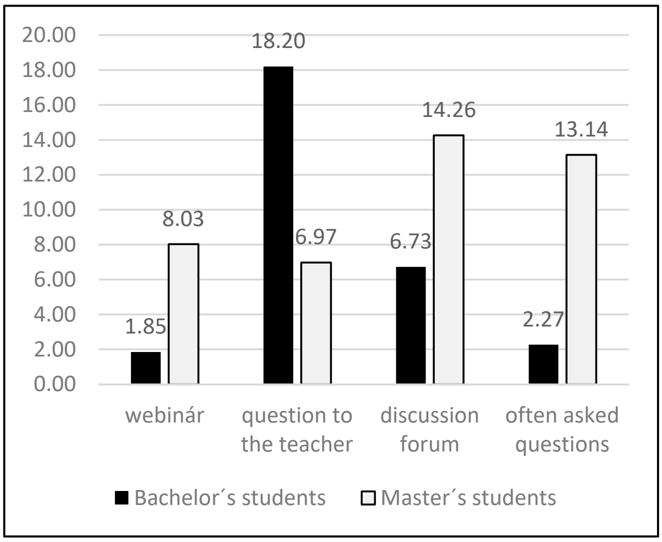

Figure 8. Average visit in options under 'Social constructivism'.

Again, we can see that there are differences between both groups of students (undergraduate and graduate) in both activity areas. We were interested in finding out whether these differences as well as the links between the monitored areas in both groups of students are statistically significant. We used the statistical method—Spearman order correlation coefficient, which expresses the degree of dependence between X and Y.

In our case, we calculated the following Spearman correlation coefficient values for both groups of students (Tables 2 and 3).

Table 2. Spearman correlation coefficient (undergraduate students).

	PEOU	**LS-D**	**LS-S**	**CAQ-CH**	**CAQ-T**	**MOOC-CC**	**MOOC-SC**
PU	0.43	−0.03	0.71 *	0.00	0.21	0.28	0.11
PEOU	1.00	0.00	0.75 *	0.19	0.29	0.38	0.07
LS-D		1.00	−0.05	−0.02	−0.04	0.02	−0.09
LS-S			1.00	0.14	0.35	0.49 *	0.09
CAQ-CH				1.00	0.04	−0.08	−0.27
CAQ-T					1.00	0.40	−0.02
MOOC-CC						1.00	0.05
MOOC-SC							1.00

* $p < 0.05$.

Table 3. Spearman correlation coefficient (graduate students).

	PEOU	**LS-D**	**LS-S**	**CAQ-CH**	**CAQ-T**	**MOOC-CC**	**MOOC-SC**
PU	0.64 *	0.70 *	0.27	0.67 *	−0.43	0.71 *	0.73 *
PEOU	1.00	0.82 *	0.03	0.57 *	−0.30	0.61 *	0.67 *
LS-D		1.00	0.14	0.69 *	−0.41	0.58 *	0.70 *
LS-S			1.00	0.12	0.29	0.15	0.02
CAQ-CH				1.00	−0.48	0.54 *	0.56 *
CAQ-T					1.00	−0.54	−0.35
MOOC-CC						1.00	0.57 *
MOOC-SC							1.00

* $p < 0.05$.

We observe in undergraduate students a high degree of bonding between PU and LS-S ($R = 0.71$) and between PEOU and LS-S ($R = 0.75$). It is the relationship between surface learning and attitudes to the use of MOOC. So, we can state that the more undergraduate students prefer a superficial approach to learning, the more they consider MOOC to be a useful and easy to use tool. Based on the results, a significant degree of binding was also observed between LS-S and MOOC-CC ($R = 0.49$), i.e., between surface learning and cognitive constructivism activities in MOOC. This can also be interpreted as suggesting that undergraduate students with a superficial approach to education tend to use activities that do not interact with other course participants. Further evaluation revealed a significant correlation ($R = 0.5$) when using video in MOOC, which undergraduate students considered the easiest way to obtain information. We can say that undergraduate students approach the use of MOOC rather than a suitable tool to help them master the curriculum with minimal effort. Other connections between observed areas in undergraduate students were not statistically significant.

A significant degree of linkage between several fields of study can be observed in the graduate students. In particular, we observe a high degree of binding between LS-D and PU ($R = 0.7$), PEOU ($R = 0.82$) as well as CAQ-CH ($R = 0.69$). Based on the correlation coefficient values given above, it can be said that the more graduate students prefer a profound approach to learning, the more they perceive the MOOC as a cognitive challenge and consider it a useful and very usable tool for learning.

In other words, based on the results we can see that the graduate students prefer deep learning. Equally significant is the degree of binding between LS-D and MOOC-CC (R = 0.58) and also between LS-D and MOOC-SC (R = 0.70), i.e., between deep learning and cognitive and social constructivism activities in our MOOC course,

Unlike undergraduate students, where these links were not confirmed at all. Based on the calculated values of correlation coefficients, we observe significant degrees of binding in the MOOC-CC between the use of tasks and exercises (R = 0.61) and theory (R = 0.53). The use of video had only a slight degree of custody (R = 0.37) regarding given access to education compared to undergraduate students. However, a significant degree of binding has been shown between the use of video and the perception of the usefulness of MOOC (R = 0.57) in graduate students. This means that the more graduate students perceive the usefulness of MOOC, the more they use video sequences in the MOOC course. In the MOOC activities included in social constructivism, there were significant degrees of links between deep learning and webinar (R = 0.63), discussion forum (R = 0.64) and frequently asked questions (R = 0.53). Based on the calculated correlation coefficient values, we got a zero link between LS-S and the activity *question to the teacher*, which was often used by undergraduate students. Based on the above results, we can conclude that in the case of graduate students with a perception of MOOC as a challenge for their education, a positive attitude towards MOOC from the point of view of its usefulness and ease of use also strengthens.

The results of our research correspond to those of [26], which also confirmed the differences between undergraduate and graduate students in LS and CAQ. The behaviour of students within our MOOC was also confirmed by the findings of Kop, Fournier, & Mak [22], that more experienced and independent students are more successful in the MOOC environment. Based on the above, it can be concluded that more frequent use of MOOCs in higher education institutions requires more space should be devoted to activities falling under the principles of social constructivism in secondary schools. In acquiring new knowledge based on the principles of cognitive constructivism, we recommend using the heuristic method in secondary schools, where the teacher acts as a moderator of the pupil's learning. In this way, critical literacy of pupils will be strengthened, which, according to Lewin [34], is one of the important prerequisites for successful mastery of MOOC.

4. Conclusions

Based on the results of the research, it can be stated that students' access to education, as well as the perception of new situations in terms of threat or challenge depends on the level of study. Master students prefer deep learning, so they care more about understanding the subject matter and the value of their knowledge, they are willing to devote more time to study. Bachelor students, on the other hand, prefer surface learning, i.e., the acquisition of the necessary knowledge without a deeper understanding and with the least effort. It was also shown that with the growth of the preference for surface learning among bachelor students and with the growth of the preference for deep learning among master students, there is also a growing perception of the usefulness and applicability of MOOCs. An important element of the research was the students' approach to the activities in our MOOC course, which were divided into cognitive and social constructivism activities. Significant differences between bachelor and master students emerged in this area. Bachelor students showed a positive correlation between their superficial approach to education and the use of MOOC activities included in cognitive constructivism. They used videos the most for their education, which we can consider the easiest way to get information. In the quantitative evaluation of attendance at individual activities of the course, bachelor students more often used the possibility of asking questions to the teacher than masters. On the contrary, master students showed a positive correlation between their perception of MOOC as a challenge and the use of activities of both cognitive and social constructivism in our course. Significant degrees of connection were also shown in the masters between their in-depth approach to education and the use of all activities of our MOOC course with a higher preference of those that were included in social constructivism. Compared to bachelor students, they made much more use of the discussion forum, webinar, theory on the topic as well as tasks and examples. We believe that differences in behaviour and attitude towards MOOC among undergraduate and graduate students reflect strongly on the way and methodology of education at secondary schools in Slovakia. Undergraduate students attended the MOOC course before they started university (before the semester), so we can attribute their behaviour to high (secondary) school students with very little or no e-learning experience. On the other hand, awareness, and responsibility for the study in terms of its need for the future and self-assertion in life is still low for 19-year-olds. Another aspect may also be the overall atmosphere in society and the speed of time when young people have higher demands on their surroundings, but not towards themselves. On the other hand, graduate students already have a bachelor's degree in higher education and know that they are required to be independent and responsible in their studies. They also have more experience with e-learning and are more open to communicating with their classmates and educators.

Based on our findings, we can state that MOOCs created on the basis of pedagogical constructivism have the potential to be a full-fledged alternative to full-time education. However, future MOOC participants need to be prepared to prefer deep learning.

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